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ORT DOCUMENTATION PAGE

(1)

1. Report Security Classification: Unclassified	
2. Security Classification Authority:	
3. Declassification/Downgrading Schedule:	
4. Distribution/Availability of Report: DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.	
5. Name of Performing Organization: Joint Military Operations Department	
6. Office Symbol: 1C	**7. Address:** Naval War College, 686 Cushing Rd., Newport, RI 02841-5010
8. Title (Include Security Classification): COMMAND, CONTROL AND EMERGING TECHNOLOGIES: IMPLICATIONS FOR THE OPERATIONAL COMMANDER (UNCLAS)	
9. Personal Authors: Sandy, Richard J., MR.	
10.Type of Report: Final	**11. Date of Report:** 1994, May, 16
12.Page Count: 29	
13.Supplementary Notation: A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Joint Military Operations Department. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.	
14. Ten key words that relate to your paper: Command and Control; C^2 Technology; Operational Command and Control; Emerging Technology	

15.Abstract: The influence of technology on the command and control process is examined in both historical and future contexts. The implications for the operational commander and the operational level of war of emerging technologies for C^2 is analyzed with reference to the principles of war. Significant advances in computers, communications, information exchange, sensor and surveillance, and decision support aids will continue to provide benefits to the C^2 process in the future. Emerging technologies will be the most useful when they are applied to facilitate and not replace the decision maker. Although the commercial sector is significantly ahead of the military sector in developing advanced communications and computer technologies, careful leveraging of these cost effective solutions and alternatives will be required to insure the military's unique needs are satisfied.

16.Distribution / Availability of Abstract:	**Unclassified**	**Same As Rpt**	**DTIC Users**
18.Abstract Security Classification: Unclassified			
19.Name of Responsible Individual: Chairman, Joint Military Operations Department			
20.Telephone: (401) 841-3414/4120	**21.Office Symbol:** 1C		

Security Classification of This Page UNCLASSIFIED

NAVAL WAR COLLEGE
Newport, R.I.

COMMAND, CONTROL AND EMERGING TECHNOLOGIES: IMPLICATIONS FOR THE OPERATIONAL COMMANDER

by

Richard J. Sandy

Naval Oceanographic Office

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Operations Department.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: Richard J. Sandy

16 May 1994

Paper directed by
Captain David Watson
Chairman, Department of Operations

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COMMAND, CONTROL AND EMERGING TECHNOLOGIES: IMPLICATIONS FOR THE OPERATIONAL COMMANDER

The influence of technology on the command and control process is examined in both historical and future contexts. The implications for the operational commander and the operational level of war of emerging technologies for C^2 is analyzed with reference to the principles of war. Significant advances in computers, communications, information exchange, sensor and surveillance, and decision support aids will continue to provide benefits to the C^2 process in the future. Emerging technologies will be the most useful when they are applied to facilitate and not replace the decision maker. Although the commercial sector is significantly ahead of the military sector in developing advanced communications and computer technologies, careful leveraging of these cost effective solutions and alternatives will be required to insure the military's unique needs are satisfied.

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COMMAND, CONTROL AND EMERGING TECHNOLOGIES: IMPLICATIONS FOR THE OPERATIONAL COMMANDER

CHAPTER I

Introduction

Command and Control. Command and control (C^2) is a vague term that lends itself to various usages and definitions. Joint Pub 3-0 defines command and control as:

> the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of a mission. Command, in particular, includes both the authority and responsibility for effectively using available resources to accomplish assigned missions.[1]

It goes on to define command as:

> Command at all levels is the art of motivating and directing people and organizations into action to accomplish missions;

and defines control as:

> Control is inherent in command. To control is to regulate forces and functions to execute the commander's intent. Control of forces and functions helps commanders and staffs compute requirements, allocate means, and integrate efforts. Control is necessary to determine the status of organizational effectiveness, identify variance from set standards, and correct deviations from these standards.

In the context of the JCS definitions command and control are complimentary functions. Command functions, in the broadest sense, involve awareness, understanding and decision making. Control functions include communication of the decision and intent, and monitoring the effectiveness of the decisions.[2] Melding of the two terms together, as command and control, defines a process rather than a system or physical entity. This process is both dynamic and iterative, and incorporates significant feedback mechanisms.

While the above definitions are concise they are also sterile in attempting to explain the concepts underlying the command and control process. J.S. Lawson, of the Naval Electronics Systems Command, attempts to further define the underlying concepts with a process model based on the premise that command and control is a cybernetic system attempting to control its surrounding environment.[3] The Lawson model consists of functional components that include *sensing* of the environment, *processing* of the sensed and external data, *comparison* of the sensed environment and the desired end state, *deciding* on a course of action, and *execution* of the action with the intent of bringing the environment closer to the desired end state. The resulting changed environment starts the process cycle over in an iterative manner. Competing models of the C^2 process are fundamentally similar with generally superficial refinements. For example, Grin proposes a cyclic model of *sense*, *analyze*, *decide*, and *act*.[4] While Sir Peter Harding (Air Chief Marshal, KCB Royal Air Force) proposes a model of *gain* early warning of attack, *analyze* the nature of the threat(s), *marshall* and order forces, and *evaluate* the success or failure continuously.[5] Other models include the SHOR model: *stimulus* (incoming information), *hypothesis* (assessment of the perceived environment), *option* (preferred course of action), *response* (action); the MORS model: *sense* (collect data), *assess* (develop information about intentions and capabilities), *generate* (develop alternate courses of action), *select* (a preferred alternative), *plan* (develop implementation details), *direct* (distribute decisions); the M/A-Com model: *monitor* situation, *assess* situation, *formulate and analyze* options, *select* options, and *direct/coordinate;* and the Boyd Cycle (or OODA Loop) model: *observation, orientation* (mental image of situation), *decision* and *action.*[6]

Critical to the understanding of the art of command and control is that the idealized goals of the process are to optimize decision making and asset utilization to insure maximum effectiveness of the battlefield forces.

The Technology Connection. In order to establish the command and control process, at a minimum, communications is an essential requirement. The C^3 (command, control and communications) system is thus a combination of the C^2 process and communication equipment and technology. The supporting function of communication is to make the exercise of C^2 more effective. But this functional dependency on communications can be a two edged sword by making the communication component a vulnerability that the operational commander has to consider in his risk assessment. Additionally, the strong historical relationship between C^2 and communication technology can divert attention and resources from the command and control process by disproportionately favoring the communications function.[7]

Communications is not the only supporting function of command and control, as evidenced by the proliferation of acronyms such as

C^3I (command, control, communications and intelligence) and C^4I (command, control, communications, computers and intelligence). The intelligence component of the C^2 process is represented in the process models by the terms *sense, gain, stimulus, monitor* or *observation*, and in part by *analyze, processing, hypothesize*, or *assess*. As with communication the C^2 process is dependent on the technology of sensor and intelligence systems.

The other major technological component that needs to be considered is data processing technology or the computer. This encompasses both the hardware that is used for organizing and displaying information, and software technology that allows the user to exploit the information for the decision making function. While the computer component is listed separately in the system acronyms (e.g. C^4I), it is interlinked not only with the command and control process, but also the communication and intelligence components.

Whether or not one of the technology components of communication, computers or intelligence is part of the C^2 process depends on its functional application at any particular time.[8] Although the current military lexicon links the technology components to the command and control process, as in C^3I and C^4I, it is not an absolute linkage. By this I mean that communications, intelligence and automated data processing have aspects that transcend the command and control process. It is only when the function and role of these technologies are relevant to C^2 and the commander's mission are they considered part of the total C^2 system.

In summary, the command and control process cannot be understood in isolation. It is supported by the technologies of communications, computers and intelligence. The process and technologies, when relevantly combined form a system for the commander to effectively execute his mission. But a system consists of more than hardware and software. The process of command and control also implies doctrine, procedures, training, organization and, most importantly, people. Although modern technology supports the command and control process, it cannot, and should not, substitute for the cognizant individuals in the decision making process.

This paper will examine the influence of technology on command and control, specifically at the operational level. While the first part has set out the relationship between the command and control process, and the synergistic technology dependent systems that allow the commander to execute the process, the second part will examine the evolution of technology and the influence it had on command and control. Because this essay is not intended to be a comprehensive historical examination, this part will be kept brief. The intended purpose is to demonstrate for the reader that there are valid and significant effects on the command and control process due to technology. The third part focuses on emerging technologies that may influence the conduct of command and control in the future, and the final section will examine potential future implications that advances in technology may have on the command and control process and the operational commander.

CHAPTER II

Historical Evolution of C^2 and Technology

The changing face of warfare due to technological advances has dictated a corresponding evolution of the C^2 process through the application of technology. The increases in weapon lethality and effectiveness, force mobility and the complexity of joint and combined operations has expanded the scope of the battle in terms of space and range, and compressed it in terms of time. Consequently the demands on the C^2 process for the operational commander has increased.[1]

By the end of the 19th Century the development of the telegraph and telephone, and the resultant increased speed of communication allowed the commander to tighten control over his operations. At the same time, this increase in control allowed for the dispersal of forces in space and time, and drove responsibility for tactical control down to lower unit commanders.[2] This communication revolution was further enhanced in the early 20th Century with the development of radio. Although the advent of rapid communication offered the operational commander and his subordinate commanders many advantages, there were disadvantages as well. The linking of the entire command structure offered opportunities for those at high level command positions to skip echelons in both ordering and countermanding orders, and micromanaging both at the tactical and operational levels of war. Additionally, while communication technology could increase the effectiveness of the operational commander, the age of electronic communication can also be characterized as introducing a key vulnerability that could be exploited by adversaries. While electronic warfare started to emerge in World War I, the first instance of radio transmission jamming dates to the Russo-Japanese War of 1904-1905.[3]

The period starting after World War II saw the development of space technology, computer technology, and further developments in electronics, communications, sensor and transportation technologies that impacted on the command and control process.

Van Crevald points specifically to two developments that impacted the C^2 process during the Vietnam War.[4] The first of these is the development of the transistor, which replaced vacuum tubes, and allowed for a major increase in the capacity to transmit information. The development of the Integrated Wide Band Communications System (IWBCS) allowed for communication transmission throughout Vietnam and the first deployment to a theater of war of a fully automated telephone system. This increase in the capacity, quality and flexibility of communications also meant an increase in complexity and specialization. Secondly, the development of the helicopter allowed the commander to quickly and personally obtain an overall view of the theater of war. These two factors, which had the potential to increase unity of command and decentralization of execution, had the opposite effect during the Vietnam War. Tactical commanders found themselves overwhelmed with requests for information and undermined in their execution of missions by the entire command structure.

Space technology brought with it the technologies of space communications, space surveillance, space weather and space navigation.[5] The consequences of these developments for the operational commander is to increase his knowledge of the environment and adversary, increase operational effectiveness of his forces, and provide for greater control and feedback of operations. While these advances have promoted the concept of "total force integration,"[6] problems of information saturation (both physical saturation of circuits and bandwidths, and "information overload" for the user) have to be carefully managed.

The last major development, that of computer technology, is interlinked with the advancements in communications and intelligence. Hardware evolution started with the single-user batch processing mainframes of the 1960s, evolved to the multi-user time-sharing mainframes of the 1970s, continued to evolve to the user-friendly desktop machines in the 1980s, and finally arrived at the networked machines of today.[7] This evolution is characterized by increasing speeds, memory and data storage, software and hardware standardization and interoperability, and a humanizing of the user interaction with both the hardware and data information. For the operational commander, the advances in computer technology have enabled him in effectively using the supporting functions of communication and intelligence. Similarly, advances in data base designs and artificial intelligence software allow for the organization and access of enormous amounts of information for the decision making process.

CHAPTER III

Emerging Technologies

Prognostication about emerging technologies and their influence on the future of command and control is fraught with uncertainty. This uncertainty is due, in part, by the political and economic factors that influence the acquisition and development of military systems. But several general assumptions can be made. First, increased reliance on advanced technology as a force multiplier is necessary due to a decreased force size, a diminishing defense budget and increasingly technological sophisticated adversaries.[1] The decreased budgetary assets will place an emphasis on the use of commercial technology to keep costs down. Secondly, joint and coalition warfare will necessitate interoperability in our C^2 systems. This will demand increased standardization in both hardware and software.[2] Although emerging technologies for C^2 can be examined in a variety of perspectives, this essay will look at them through five functional areas: information exchange, decision support, communications, computers and surveillance. Understandably, specific technologies will overlap the functional areas.

<u>Information Exchange</u>. The key to maximizing information exchange while reducing information overload lies in data base management and design, network connectivity and advanced query systems. As information is the raw material on which decisions are

made, the operational commander requires the necessary critical information in a timely manner.[3] Informational data bases will increasingly take on two characteristics for the command and control process: relational and distributed. Relational data bases will maximize retrieval of the right information for the right people through the relational query system, and distributed data bases will minimize redundancy while placing the needed information closer to the primary users. Network technology is moving along on two fronts. Fiber optic technology will continue to advance transmission and switching speeds,[4] and optics will be integrated into the computer at all levels with the eventual emergence of the all-optical digital computer.[5] Finally, wireless networks, resembling cellular phone networks, will permit global mobility and rapid reconfiguration of fixed-site C^2 facilities.[6]

Decision Support. The essence of command and control is decision making. The software technology of artificial intelligence will support that process by analysis of situations and courses of actions, and providing a concrete rationale for its recommendations. While the field of artificial intelligence has made significant advances, it has also fallen short of its initial promises. Although much development remains before its usefulness can be fully exploited, the potential of artificial intelligence to support the operational commander is immense. Two subareas of artificial intelligence hold the greatest potential. Expert systems, using rule based schemas, will absorb the function of the more routine decision making.[7] While expert systems do not currently attempt to mimic the reasoning process that human experts use,[8] advances in understanding the human thought process will lead to generic artificial intelligence systems that provide a greater utility over a range of problems. The second subarea is that of natural language processing systems that permit computer/user interaction based on free-form written text or verbal commands.[9] Natural language technology will facilitate the user interface of computer based systems and allow for increased understanding and dissemination of communications. An area related to artificial intelligence is that of fuzzy set theory. Fuzzy set theory provides a mathematical framework for the comparisons of vague, non-quantifiable parameters or processes.[10] It's utility for C^2 is one of duplicating human 'judgement' in the decision making process.

Communications. Communications work to move informational data, decisions and feedback information throughout the command structure. The C^2 requirement is for secure, robust capabilities that provide for a level of redundancy to insure continuous functionality for the operational commander. Communication technologies are inexorably linked to the functional areas of information exchange (specifically fiber optic and optical switching technologies), decision support and computers, and, as such, do not warrant detailed attention here. However, an important point to understand is that the commercial sector leads the military establishment in communication technologies and technology improvements.[11] This bodes well for the C2 process as the military can capitalize on incorporating cost effective off-the-shelf technologies now and in the future.

Computer Technology. Computer technology is advancing over several broad categories. Those categories that will have an impact on the command and control process include, in addition to the previously mentioned optical computing, engineering architecture, advanced chip technologies, user interface technology and flat panel displays. Like communication technology the computer advances are being driven primarily by the commercial sector with hardware generation cycles lasting only eighteen months. Each generation is seeing a doubling of memory and speed with the cost holding constant.[12]

Parallel processing will continue to dominate advances in computer engineering architecture and will likely take the lead over sequential processors by the end of the century.[13] To gain full advantage of the performance of the system architecture, scalable algorithm software development will increase and likely trend towards standardization. For the C^2 process, the increased speed will allow exploitation of artificial intelligence software and other compute intensive software.[14] Integrated circuit technologies are also advancing to the benefit of the operational commander. Very large scale integrated circuits (VLSIC) and very high speed integrated circuits (VHSIC) will further improve computer speed performance while providing for high reliability, mobility and radiation hardening.[15] These advances impact both processor and graphics architecture, and have implications for communications, surveillance, decision support and information exchange.

The user interface to the computer will improve through increased use of graphics, voice and gesture.[16] Flat panel display technology will be one aspect of this improvement while simultaneously increasing reliability and mobility. Mark Weiser, of the Palo Alto Research Center, envisions this trend toward increased user-friendliness will bring out awareness on the part of the user of the other people on the system and reduce the man versus machine mentality that can invade the processing environment.[17]

Surveillance/Sensors. Emerging sensor and surveillance technologies are emphasizing distributed unattended sensors[18] through the Advanced Research Projects Agency's (ARPA) Innovative Technology Development program. Future technology will also emphasize small, low power, independent elements that can form large virtual sensor arrays through short distance communications.[19] Both passive and active, these independent but 'cooperating' sensor elements will provide the operational commander with a surveillance and intelligence capability of increased resolution, greater flexibility and reduced vulnerability.

CHAPTER IV

Implications for the Operational Commander

Command and control is ultimately about controlling combat and military forces. The process attempts to reduce uncertainty in both assessments and decision making. While technology is increasingly affecting the C^2 process, that affect can offer advantages and disadvantages. The level of effectiveness of emerging technologies can be examined in a variety of ways, but a practical manner for the operational commander is in terms of the principles of war.

Objective and Unity of Command. Unity of command is designed to ensure the accomplishment of the operational objective(s) by providing for unity of effort through organizational responsibility and control. The increased pace and geographical range of the modern battlefield can stress the decision making process for the operational commander. Rapid, mobile and high volume communications and computers will support a centralized command structure. Emerging technologies will facilitate the collection and dissemination of information, and provide fused and filtered intelligence to the various command echelons critical to the objective. Both feedback into the operational commander and command decisions moving down to the tactical and unit commanders, through secure, redundant networks and communication facilities, will allow for unity of effort through centralized command and decentralized execution. The adoption of standards, modular mobile C^2 systems, and wireless networks will allow the commander freedom of movement in a rapidly changing battlefield environment without compromising his command unity.

The increased reliability and complexity of the future technologies also have the potential to adversely affect unity of command. Weissinger-Baylor likens the naval decision making process to a garbage can model that is characterized by ambiguities in technology, preferences and participation.[1] Technical ambiguity results from ignorance of available options and/or the consequences of each alternative. While artificial intelligence, computer advances and advanced sensors can go far in eliminating technological ambiguity, they must also insure the users are not forced into becoming narrow and short-sighted specialists. The same technology that supports unity of command and focused objectives will also allow for centralized execution and command echelon skipping in the giving and countermanding of orders. The ability of high level decision makers to subvert the authority and responsibility of the operational commander, and even tactical commanders, in the theater of operations will not, and probably should not, be controlled by future technological innovations. Only through discipline, doctrine and responsible and knowledgeable leadership will the phenomena of echelon skipping be avoided.

Offensive, Mass, Economy of Force and Maneuver. Modern warfare at the operational level requires control, coordination and synchronization of joint and coalition forces to effect the principles of mass, economy of force, maneuver warfare and offensive action. The principles of maneuver and exploitation of offensive actions imply speed and agility in both forces and weapons. As a result this puts a premium on the C^2 process in terms of speed of assessment and speed of decision making. The C^2 process of the future will act as a force multiplier affording freedom of movement to one's own forces while lessening the risk. Future technologies of parallel processing and artificial intelligence will substitute for a certain level of decision making and provide the speed necessary to counter the adversarial position and exploit their weaknesses in a decisive manner. The emerging technologies will allow future commanders at all levels to have a comprehensive and detailed view of the battlefield to insure effective operations.

Security. While enhancing freedom of movement, high technology C^2 systems will require prudent risk management. Increased use and dependency on sophisticated technology makes command and control vulnerable in a variety of ways. Adversaries who manage to penetrate or jam these systems put the opposing military forces at risk. Identification of critical system components and nodes through the exploitation of signature emissions target the C^2 process as a key vulnerability. Additionally the systems exhibit deterioration and defects. The operational commander will require both redundancy and backup functionality, and must insure system operators and users have the ability to function in a degraded environment. The increasing dependency on using commercial off-the-shelf hardware for key areas of the command and control process has the potential to exacerbate the security dilemma. Program and acquisition managers must be cognizant of the specific and unique requirements the military needs.

Surprise. Exploiting the principle of surprise is a key component to an effective and responsive C^2 process. All of the emerging technology functional areas will allow the future operational commander to utilize this principle to maximum effectiveness. Rapid, accurate, filtered and fused information exchange, coupled with advanced, distributed, high resolution sensor and surveillance capabilities will provide the commander with the necessary input on which to base his decision making. Likewise, advances in decision support aids and computer technology will speed the decision making process in a rationally supportable manner. Lastly, secure and robust communications will enable the commander to pass his decisions through the command structure for timely execution in a manner that is personal and maintains the integrity of his intent. But commercial technology advances also empower a sophisticated adversary. Commercially available space technologies, including surveillance, communications, weather and navigation, work to increase the visibility into the battlefield for an adversary's command and control process, as well as our own.

Simplicity. The final principle, that of simplicity, mandates uncomplicated operational plans and precise, clear orders. The command and control process must contribute to the understanding of all cognizant personnel, and not burden the operational commander with information overload or subordinate tactical commanders with unnecessary voluminous requests for more information. The emerging technologies have the potential to keep things simple for the commander if the technologies are implemented in a manner responsive to the commander's needs. Technology for the sake of technology and not managed to the benefit of the decision makers can overwhelm the C^2 process and become a hindrance. As options, situations and the operational environment become increasingly complex, emerging technologies have the potential to eliminate superfluous details and reduce analysis parameters through predictive decision making. The result for the commander will be a concise view of his options and courses of action - simplicity in an increasingly complex situation.

CHAPTER V

Conclusions

The command and control process has been influenced by technology throughout history. Technological advancements will continue to result in greater C^2 capability that reduces the uncertainty and penetrates Clausewitz's fog of war for the operational commanders and decision makers.

The C^2 process cannot, however, be understood in isolation. Supporting functions and components are integral to understanding the process and system the commander operates in. The command and control process and its supporting functional components must be simple and easy to use for the operators, work in an interoperable environment, allow for the dissemination of clear, concise and timely information and directives, and most importantly, provide the commander with what he needs and wants. Emerging technologies will not replace the decision maker, but will facilitate the decision making process.

Challenges for the future include:

- leveraging of cost effective commercial communications and computer technologies, while meeting the military's requirements for secure and survivable components,

- identifying emerging technologies that relate to the needs of the command and control community and fostering their development, and

- insuring that technological components and their development don't dictate the function and structure of the command and control process.

While future C^2 challenges can be met, in part, by technological advancements, that is not the sole avenue to explore. Advances in training, doctrine, organization and operations can, independently of any technology, improve and advance the command and control process to meet the challenges of the future.

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